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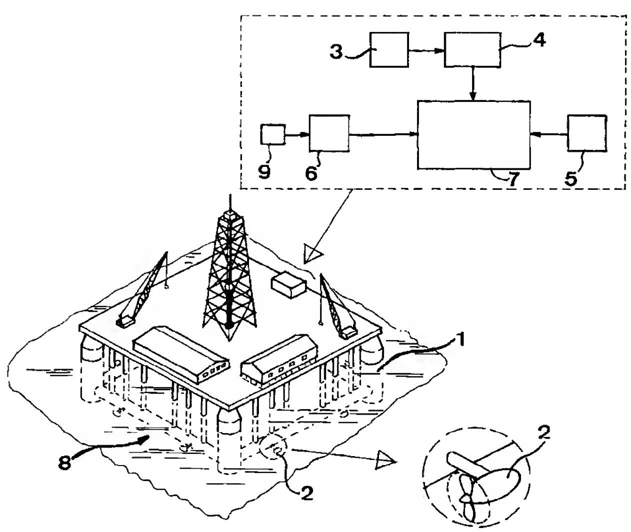
(54) Title: A METHOD AND A DEVICE FOR CONTROLLING THE POSITION OF AN OBJECT



(57) Abstract: A device for controlling the position of an object located in water towards a reference position being constant over time comprises means (3) for measuring the real position of the object, means (4) for comparing the measured position with a reference position desired for the object, means (7) for calculating forces to be applied on the object for forcing it towards said reference position on the basis of the result of said comparison and an apparatus (2, 8) for applying said forces to the object (1) for forcing it towards said reference position. The device also comprises means (6) adapted to establish a value of the acceleration of the object at said time. The calculating means (7) is adapted to consider said acceleration value when calculating said forces.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

A method and a device for controlling the position of an object

FIELD OF THE INVENTION

The present invention relates to a method for controlling the position of an object located in water towards a reference position being constant over time, in which the real position of the object is measured, this measured position is compared with said reference position desired for the object, forces to be applied to the object for forcing it towards said reference position are calculated on the basis of said comparison and the forces so calculated are applied on the object for forcing it towards said reference position, as well as a device for carrying out such a method.

The object may be any kind of object immersed to different extent in water, such as a ship, a platform for different types of work at sea, such as for oil drilling, diving operations, cable operations, lifting operations, on- and off-loading of cargo, fuel or oil for mentioning some examples.

The position desired is a fixed position, so that the control is made for keeping the object, such as a marine vessel, in the same position but the object may accordingly be designed for transport during other periods of time, such as in the case of a ship. Thus, "constant over time" does not mean forever, but for the period of time during which the control method is to be applied to the object.

The invention is also especially applicable to situations in which comparatively rough conditions may occur, which makes a device for controlling the position of the object in question strongly needed, such as far out at sea were the influences of currents, wind and waves upon the object in question may be significant and varying substantially over time.

Accordingly, the aim of a method and a device of this type is to counteract these forces applied by the nature on the object for keeping the object in said desired position.

PRIOR ART

A device and a method of the type defined in the introduction already known will now be briefly described while making reference to the appended figs 1 and 2. We will now assume that the object is a vessel placed out at sea which has to be held in a position fixed over time. Thus, this object is dynamically positioned and the position p thereof may be described as

$$p = \begin{pmatrix} x \\ y \\ \varphi \end{pmatrix} \qquad (1)$$

x, y, and φ are the earth-fixed positions, i.e. north, east and compass heading (the angle made to the north direction), respectively, as illustrated for an object 1 in fig 1. Accordingly, "position" as used in this disclosure is to be interpreted as possibly also including a direction information, i.e. an orientation of the object, except for the position coordinates. Wind, ocean currents and waves may influence the object away from this desired reference position. It is illustrated in fig 2 how a vessel in the form of a platform of this type is provided with a number of driving means in the form of thrusters 2 operated for applying the forces necessary for forcing the object towards the reference position, i.e. for continuously keeping it as close as possible to

that position. A thruster is a general device that is capable of producing forces on the object/vessel. Examples are all kinds of propellers (main propellers, tunnel thrusters, compass thrusters), water jets, rudders or any other active or passive device with the purpose of contributing in the control of the vessel. These thrusters are preferably individually adjustable with respect to the direction of the forces applied thereby on the object.

The disturbances and other forces acting on the vessel are denoted τ_d and consists of environmental loads such as wind, ocean currents and higher order wave loads and other external loads such as forces due to cables, hawsers, mooring system and crane operations. These disturbances may be separated into three parts according to:

$$\tau_d = \tau_b + \tau_{sv} + \tau_{rv} \qquad (2)$$

in which τ_b contains more or less constant bias forces while τ_{sv} and τ_{rv} contain unknown zero – mean slowly and rapidly, respectively, varying forces. The control input for devices of this type already known has been calculated as τ_{PID} according to the following formula (3):

$$\tau_{PID} = -k_P (p_{ref} - p) - k_v \hat{\dot{p}} - k_i \int_0^t (p_{ref} - p)dt \qquad (3)$$

In which p_{ref} is the reference position desired for the object, p is the measured position for the object, $\hat{\dot{p}}$ is the estimated velocity of the object and k_p, k_v and k_i may be constant or time varying matrices. All terms may be described according to the position above, i.e. including x–, y– and φ - components, and the control force to be applied to the object may also be described as:

$$\tau_{PID} = \begin{pmatrix} \tau_x \\ \tau_y \\ \tau_\varphi \end{pmatrix} \qquad (4)$$

The first of the three terms $- k_p (p_{ref} - p)$ describes the position error, the second one $- k_v \hat{\dot{p}}$ describes the velocity error and the third term $- k_i \int_0^t (p_{ref} - p)dt$, the integral of the position error over time, will when properly tuned compensate for the constant bias disturbance τ_b in (2).

Accordingly, the integral term is therefore compensating for constant forces by forming the average of all external forces acting upon the object over a longer time. It is to be noted that substantial control forces τ_{PID} may be necessary although $p_{ref} = p$ for preventing the object from leaving this desired position, and would in such a case no forces at all be applied to the object the position error will rapidly be unacceptably large. Furthermore, it will cost a lot of extra power to correct the position when it has drifted too far away from the reference position desired.

Although this type of existing methods and devices for controlling the position of an object in water are well functioning there is always a desire to make improvements thereof, since very high costs are oftenly involved. In the case of an oil drilling rig as said object the mass thereof is significant and high demands are put on said apparatus, such as a number of thrusters, for applying the control forces on the rig and the power consumption thereof is important. This means that the working conditions and the working results would be remarkably improved would an improvement of the positioning performance be possible.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a method and a device of the type defined in the introduction being improved in at least some aspect with respect to the methods and devices of this type described above.

This object is obtained by providing such a method in which a value of the acceleration of the object is also established and said calculation of said force is carried out while considering the acceleration value so established. The introduction of the acceleration may be made according to the formula (5):

$$\tau = \tau_{PID} + \tau_{FF} - h_a(f)\ \ddot{p} \qquad (5)$$

In which τ_{FF} is a feed-forward term, $h_a(f)$ is some kind of filter and $\ddot{p}$ is the acceleration value established of the object. It is pointed out that the invention is not at all restricted to this formula (5), and the term τ_{PID} may be replaced by a term differing from τ_{PID} as defined above. The introduction of an acceleration value in the calculation of the forces to be applied on the object for controlling it towards the desired reference position results in a number of advantages. It is easier to detect an acceleration than a velocity and an acceleration may be detected very early, so that the control forces may be rapidly adapted to the circumstances prevailing for the moment. The acceleration may be rather high already without any noticeable deviation of the position or any noticeable velocity of the object. It would then be very advantageous to interfere and apply forces counteracting the future result of such an acceleration before the real position has been changed too much and before the object has reached a considerable velocity. Accordingly, the invention provides for the possibility to improve the positioning performance by reducing the average deviation of the position of the object from said reference position. Furthermore, it may lead to a more uniformous load on the driving means of an apparatus, such as

thrusters, for applying forces to the object prolonging the lifetime thereof. The fuel efficiency of such an apparatus may also be improved. It may also in some applications be possible to reduce the number of driving means of such an apparatus and still obtain the same position performances as through the devices already known would that be a preferred solution.

According to a preferred embodiment of the invention said value of the acceleration of the object is established totally or partially through an actual measurement of the acceleration of the object. Thus, an "acceleration-signal" (filtered estimate, or whatever) that is totally or partially (in the sense that other measurements and/or control inputs can be used as well) based on an actual acceleration measurement is implicitly or explicitly used for the calculation of the control forces to be applied on the object. This is a totally new approach for position controlling, since methods already known use position measurements only.

According to another preferred embodiment of the invention the acceleration value so established is introduced as a part of a term having an influence upon said calculated forces increasing with the magnitude of this term. An example thereof is illustrated in formula (5) above.

According to another preferred embodiment of the invention said acceleration value term part is multiplied by an amplifying factor determining the influence of the established acceleration upon the forces used for controlling the object towards the reference position. An example of such a amplifying factor is when in formula (5) $h_a(f) = k_a$ (se discussion following), and the magnitude of this factor will decide how strong the position control responds to an acceleration of the object. Thus, if this amplifying factor is set to a high level the control will be highly responsive to accelerations and the positioning performances will be improved. However, a higher amplifying factor does of course also put higher demands on the maximum power available by means

for applying the forces on the object for forcing it towards the reference position. Accordingly, it will be preferred to adjust the amplifying factor for adaption of the position controlling procedure to the demands of accuracy thereupon for finding an optimum with respect to said demands of accuracy and the costs for an apparatus used to apply the forces calculated on the object. This amplifying factor may in the reality be considered as a mass value, and it has turned out to be advantageous to select the amplification factor so that the forces applied on the object will be greater than $m\ddot{p}$, in which m is the mass of the object and $\ddot{p}$ is said acceleration value established. Such a high amplifying factor has turned out to be necessary, since said acceleration value established will be comparatively low, but great forces are needed for forcing in the object, such as an oil drilling rig, back to a reference position.

According to other preferred embodiments of the invention the method is carried out in a closed feedback loop and the measurement of the position of the object and the establishment of the acceleration value thereof as well as said calculation of said forces are carried out substantially continuously with the aim to continuously keep the object in said reference position, which is of course desirable for keeping position deviations and fuel consumption low.

Different embodiments of the invention relating to a combination of the introduction of the acceleration value in said calculation and the method according to the prior art are defined in other dependent claims.

According to another preferred embodiment of the invention components of the acceleration of the object changing with a high frequency are filtered out and not considered when establishing said acceleration value of the object. Such high frequency components are for instance components having the frequency of sea waves in said water. These acceleration compo-

nents are changing far too fast for being considered and have to be filtered out. Considering thereof would only result in unnecessarily disturbed operation of the driving means used to realise the forces needed. The most dominating effect of the waves are the higher orders of wave forces having an influence upon the object changing according to a much lower frequency, and the acceleration resulting from these wave or sea forces will be considered by the present invention. According to other preferred embodiments of the invention the position of a marine vessel is controlled for keeping this vessel in a fixed position, and said marine vessel is advantageously an oil drilling rig, for which it is of great importance to have a high position accuracy.

The function and the advantages of a device according to the invention and the preferred embodiments thereof according to the appended device claims appear clearly from the discussion above of embodiments according to corresponding method claims.

The invention also relates to a computer program and a computer readable medium according to the corresponding appended claims. It is easy to understand that the invention as defined in the appended method claims is well suited to be carried out by program instructions from a processor operated by a computer program provided with the program steps in question.

Further advantages as well as advantageous features of the invention appear from the description following below and the other dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

With reference to the appended drawings, below follows a specific description of preferred embodiments of the invention cited as examples.

In the drawings:

Fig 1 is a schematic view illustrating an object in general and how the position thereof is determined,

Fig 2 is a very schematic view of a platform in the form of an oil drilling rig to which a device for controlling the position thereof according to the invention is applied,

Fig 3 is a simplified graph used to explain the invention,

Fig 4-8 are diagrams obtained by simulations for the north position of an object versus time, the resulting pitch angles of the object versus time, the Fourier transform of the north position of the object, the Fourier transform of the pitch motion of the object and the total power consumption of thrustors for the positioning control of the object versus time, respectively, for a method according to the invention considering the acceleration of the object (solid lines) and for a prior art method not considering the acceleration of the object (dotted lines).

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

It is schematical illustrated in fig 2 how a device according to the invention for controlling the position of the object (oil drilling rig) 1 comprises means 3 for measuring the real position of the object at a time, means 4 for comparing the measured position with a reference position desired for the object at this time, means 6 for establishing a value of the acceleration of the object at this time and means 7 for calculating forces to be applied on the object for forcing it towards a reference position. The device also comprises an apparatus 8 having a number of thrusters 2 for applying said forces on the object for forcing it towards the reference position. The means for establishing the acceleration value is combined with means 9 for filtering out com-

ponents of the acceleration changing with a high frequency in the order of that of sea waves, so that these are not considered by the calculating means 7.

Accordingly, we consider a low frequency dynamic model of the body (object) motion, which means that the model behaviour is sufficiently correct when we use constant acceleration feedback τ_a according to formula (6) even when the acceleration signal has been filtered:

$$\tau_a = - h_a (f)\ \ddot{p} \tag{6}$$

This means that:

$$m \cdot \ddot{p} + D\dot{p} + kp = \tau_{PID} + \tau_{FF} - h_a (f)\ \ddot{p} \tag{7}$$

$$(m + h_a (f))\ \ddot{p} = - D\dot{p} - kp + \tau_{PID} + \tau_{FF} \tag{8}$$

Where D is a damping caused by the system, such as "water friction" and m is the mass of the object.

This means that the acceleration feedback can be regarded as a virtual increase of the systems mass. An advantage is that this system is made less sensitive to the unknown slowly varying disturbances τ_{sv}, while the closed-loop regulation is used. As already stated above, the consequences of introducing the acceleration into the position control are improved positioning performance, less oscillating thruster usage and improved fuel efficiency for the thrusters. This means a possibility to reduce the amplitude of the deviations (the oscillations) of the object around the desired reference position. The total power to be used or the fuel consumption necessary for maintaining a position with a determined accuracy may be remarkably reduced. However, it is possible to use the same amount of power and fuel as before but instead improving said accuracy. However, if there is no desire to increase the accuracy, it may be possible to

reduce the number of thrusters, for instance use four instead of five, for obtaining this accuracy thanks to less power required therefor. It is very costly to keep for instance an oil drilling rig in a fixed position for drilling and a reduction of the power consumption therefor with let us say 10 % would result in a tremendous saving of costs.

If h_a (f) (se the formulas (6) – (8)) is selected to be k_a as discussed further above it will act as an amplifying factor, which may be constant or varying with time and in the reality may be considered as a mass value added to the real mass of the object. However, it is possible to use formula (9) instead:

$$h_a(f) = k_a \frac{1}{1+T_a f} \tag{9}$$

This means that this term as introduced in the calculations will act as a low pass filter. If we set m = 1, T_a = 1, k_a = 3 for this h_a (f) and for any other linear low pass filter, at low frequencies, i.e. $f \to 0$, the acceleration loop is active and the mass increases to $(m + h_a)(0) = m+k_a$, which is equivalent to a constant acceleration feed back. On the other hand, when f increases the virtual mass converges towards the actual mass m, so that $(m + h_a)(\infty) = m$. The increase of mass means that undesired accelerations that the disturbances cause will be attenuated. The usage of filters (or time-varying gains for that matter) on the acceleration signals and the other ones as well, provides an increase in flexibility of the control method.

Fig 3 illustrates the radius r defining the positioning accuracy of a device according to the invention, in which the line 10 defines the limit which the position of the object will never pass assuming that the reference position is located in the centre O of the systems of coordinates. For the invention formula (9) is valid:

$$r = k \cdot \frac{1}{1+k_A} \tag{10}$$

In which k is a constant. This illustrates how the radius and by that the accuracy increases with an increasing amplifying factor k_A. Accordingly, by increasingly considering the acceleration of the object, i.e. by increasing the amplifying factor k_A, it will be possible to stay within a more narrow region defined by the radius.

Simulations have been carried out for a semi-submersible drilling rig. The rig was exposed to winds of average speed 24 m/s, a current with average speed 0,3 m/s and waves of significant wave height 8 meters and a peak period of 12 seconds. All environmental loads attacked the rig from a mean direction of 10 degrees, i.e. from north – north – east. This means that when the desired heading was $\varphi = 0$ degrees, it was mainly the surge dynamics that was exposed. The simulation was run for 3600 seconds and the acceleration feedback according to the invention was enabled at t = 1800 seconds. k_A was chosen to be 2 m $\approx 132 \cdot 10^6$ kg. The results of the simulations are illustrated in the diagrams in fig 4-8. Fig 4 illustrates the north position x with (solid) and without (dotted) acceleration feedback for the platform, whereas fig 5 illustrates the resulting pitch angles with (solid) and without (dotted) acceleration feedback according to the invention. It is noted that the phase lag in the thrustor signal has been reduced with the acceleration feedback, which means that it is possible to counteract the varying disturbance before it manifests itself in velocity and position deviations. The Fourier transforms of the north position x with (solid) and without (dotted) acceleration feedback and pitch motion with (solid) and without (dotted) acceleration feedback are shown in fig 6 and 7 and show that the oscillations have been attenuated significantly. As predicted, the simulations show that the positioning was improved and a smaller variance in the commanded thrustor force signal was obtained. It is worth noting that the original

PID-like controller was unaltered, which means that it is possible that the performance defined as positioning accuracy may be enhanced even more with proper tuning thereof.

Fig 8 illustrates the total thrustor power consumption with (solid) and without (dotted) acceleration feedback, and the variance has been decreased here to. However, the mean power consumption was reduced by only one percent. At least the total power consumption did not increase at the expense of improved positioning accuracy.

The invention is of course not in any way restricted to the preferred embodiment described above, but many possibilities to modifications thereof would be apparent to a person with ordinary skill in the art without departing from the basic idea of the invention as defined in the appended claims.

Such a person may without any problem mention a number of different components available on the market to be used as each of said means discussed above.

Claims

1. A method for controlling the position of an object (1) located in water towards a reference position being constant over time, in which the real position of the object is measured, this measured position is compared with said reference position desired for the object, forces to be applied to the object for forcing it towards said reference position are calculated on the basis of said comparison and the forces so calculated are applied on the object for forcing it towards said reference position, characterized in that a value of the acceleration of the object is also established, and that said calculation of said forces is carried out while considering the acceleration value so established.

2. A method according to claim 1, characterized in that said value of the acceleration of the object is established totally or partially through an actual measurement of the acceleration of the object.

3. A method according to claim 2, characterized in that said value of the acceleration of the object is established by direct measuring of the acceleration.

4. A method according to any of claims 1-3, characterized in that the acceleration value so established is introduced as a part of a term having an influence upon said calculated forces increasing with the magnitude of this term.

5. A method according to claim 4, characterized in that said acceleration value term part is multiplied by an amplifying factor determining the influence of the established acceleration upon the forces used for controlling the object towards the reference position.

6. A method according to claim 5, <u>characterized</u> in that said amplifying factor is adjusted for adaptation of the position controlling procedure to the demands of accuracy thereupon, so that the amplifying factor is increased when said demands are increased.

7. A method according to claim 6, <u>characterized</u> in that said amplification factor is adjusted so that the forces applied on the object will be greater than $m\ddot{p}$, in which m is the mass of the object and $\ddot{p}$ is said acceleration value established.

8. A method according to any of claims 1-7, <u>characterized</u> in that it is carried out in a closed feedback loop.

9. A method according to claim 8, <u>characterized</u> in that the measurement of the position of the object and the establishment of the acceleration value thereof as well as said calculation of said forces is carried out substantially continuously with the aim to continuously keep the object in said reference position.

10. A method according to any of claims 1-9, <u>characterized</u> in that a value of the velocity of the object is established and compared with a reference velocity desired for the object at said time, and that said calculation of said forces is carried out while considering the result of this comparison of velocities.

11. A method according to claim 10, <u>characterized</u> in that said velocity value is established by estimating the velocity of the object.

12. A method according to any of the preceding claims, <u>characterized</u> in that the integral of the difference between said reference position and said measured position over time is formed, and the result of this integration is used for forming

an average of all constant external forces applied on the object, and that said calculation of the forces to be applied on the object is carried out while considering this average of external constant forces.

13. A method according to any of the preceding claims, characterized in that it is the position including two coordinates in the horizontal plane of a Cartesian system of coordinates that is measured and compared with a reference position including corresponding coordinates.

14. A method according to claim 13, characterized in that said measured and reference position also include the orientation of the object in the horizontal plane of said system of coordinates.

15. A method according to any of the preceding claims, characterized in that different forces are applied to the object for influencing the object differently.

16. A method according to claim 15, characterized in that said forces are applied to the object for influencing the object along a first line and/or a second line perpendicular to the first one and/or to turn around a vertical axis through the real position of the object.

17. A method according to any of the preceding claims, characterized in that components of the acceleration of the object changing with a high frequency are filtered out and not considered when establishing said acceleration value of the object.

18. A method according to claim 17, characterized in that acceleration components having a frequency of sea waves in said water are filtered out.

19. A method according to any of the preceding claims, characterized in that the position of a ship is controlled for keeping the ship in a fixed position.

20. A method according to any of claims 1-18, characterized in that the position of a marine vessel is controlled for keeping this vessel in a fixed position.

21. A method according to claim 20, characterized in that it is the position of a marine vessel in the form of an oil drilling rig that is controlled.

22. A computer program directly loadable into the internal memory of a computer, comprising software for controlling the steps of any of claims 1-21 when said program is run on the computer.

23. A computer program according to claim 22, provided at least partially through a network as the Internet.

24. A computer readable medium, having a program recorded thereon, where the program is to make a computer control the steps of any of claims 1-21.

25. A device for controlling the position of an object located in water towards a reference position being constant over time comprising means (3) for measuring the real position of the object, means (4) for comparing the measured position with said reference position desired for the object (1), means (7) for calculating forces to be applied to the object for forcing it towards said reference position on the basis of the result of said comparison and an apparatus (8) for applying said forces on the object for forcing it towards said reference position, characterized in that the device also comprises means (6) adapted to establish a value of the acceleration of the object at said time, and that said calculating means is

adapted to consider said acceleration value when calculating said forces.

26. A device according to claim 25, characterized in that said means (6) is adapted to establish a value of the acceleration of the object totally or partially through an actual measurement of the acceleration of the object.

27. A device according to claim 26, characterized in that said means (6) is adapted to establish a value of the acceleration of the object by direct measuring of the acceleration of the object.

28. A device according to any of claims 25-27, characterized in that said calculating means (7) is adapted to base the calculation of the forces to be applied on said object on a term having said acceleration value established as a part, the influence of said term upon said calculated forces increasing with the magnitude of this term.

29. A device according to claim 28, characterized in that said calculating means (7) is adapted to multiply said acceleration value term part by an amplifying factor determining the influence of the established acceleration upon the forces used for controlling the object towards the reference position.

30. A device according to any of claims 25-29, characterized in that it comprises means (5) for establishing a value of the velocity of the object and comparing this value with a reference velocity desired for the object at said time, and that said means (7) is adapted to calculate said forces while considering the result of this comparison of velocities.

31. A device according to any of claims 25-30, characterized in that said means (3) is adapted to measure a position of the

object comprising two coordinates in the horizontal plane of a Cartesian system of coordinates and said means (4) is adapted to compare these coordinates with the corresponding coordinates of the reference position.

32. A device according to claim 31, characterized in that said means (3) are adapted to measure a position and compare it with a reference position both also including the orientation of the object in the horizontal plane of said system of coordinates.

33. A device according to any of claims 25-32, characterized in that said apparatus (8) comprises a plurality of driving means (2) adapted to apply a driving force on the object (1) for influencing the object in different senses.

34. A device according to claim 33, characterized in that said driving means are thrusters (2).

35. A device according to claim 33 or 34, characterized in that said driving means (2) are adapted to influence the object along a first horizontal line and/or a second horizontal line perpendicular to the first one and/or to turn around a vertical axis through the real position of the object.

36. A device according to any of claims 25-35, characterized in that it comprises means (9) for filtering out components of the acceleration of the object changing with a high frequency for not being considered when establishing said acceleration value of the object.

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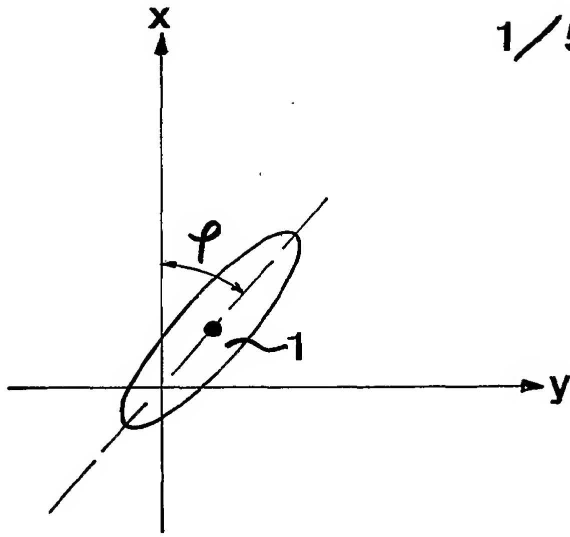

Fig 1

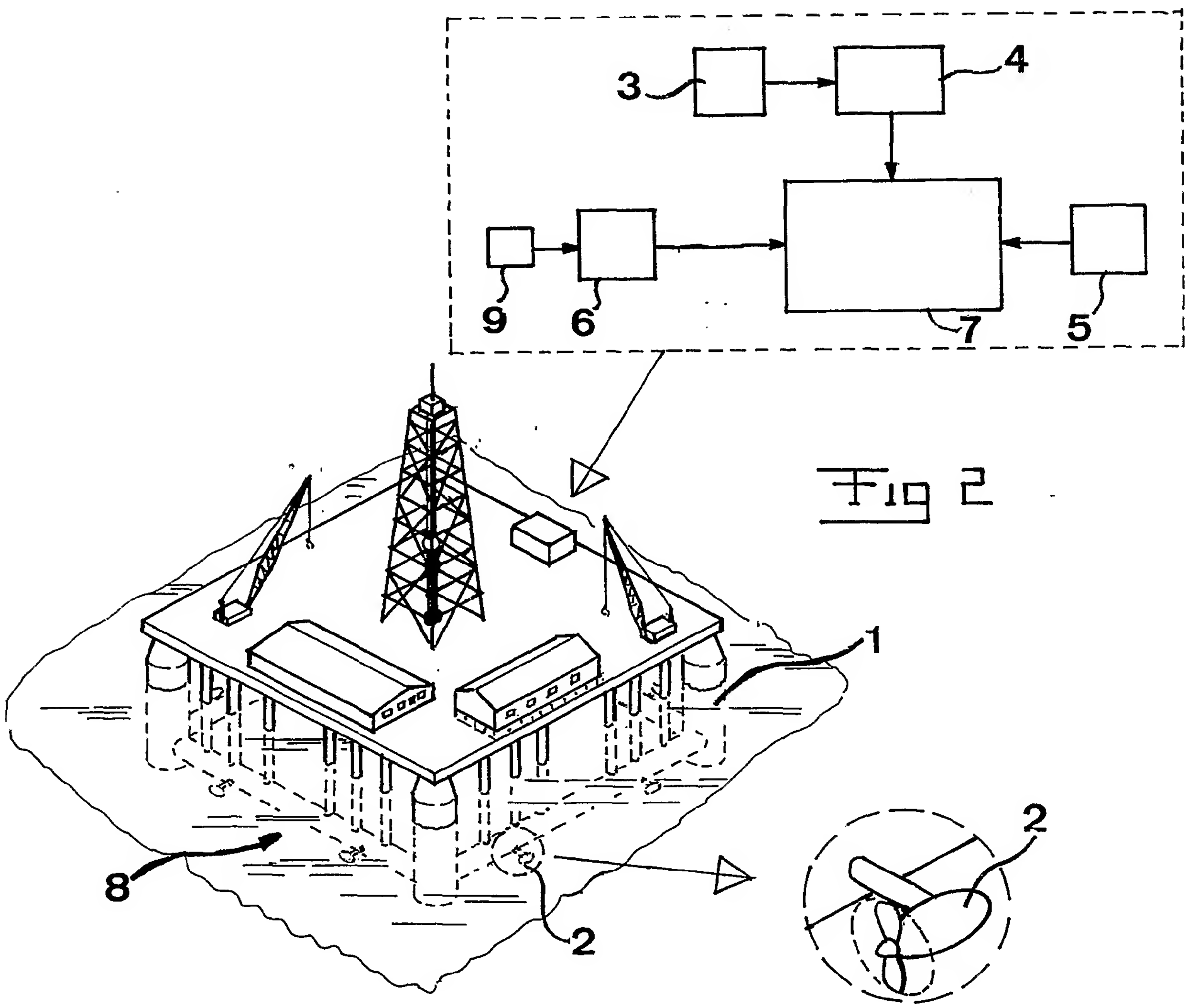

Fig 2

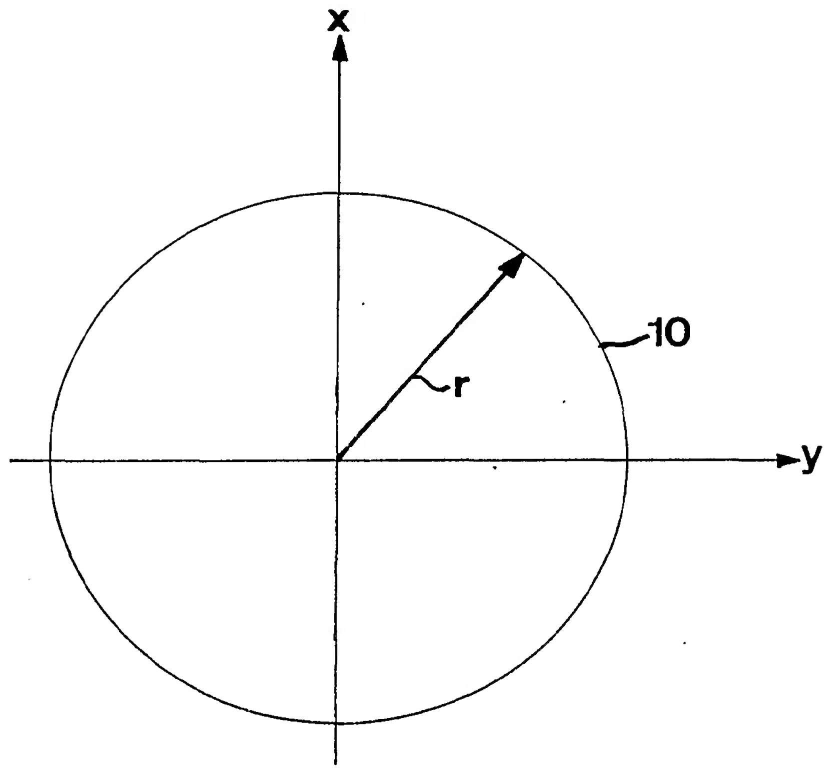

Fig 3

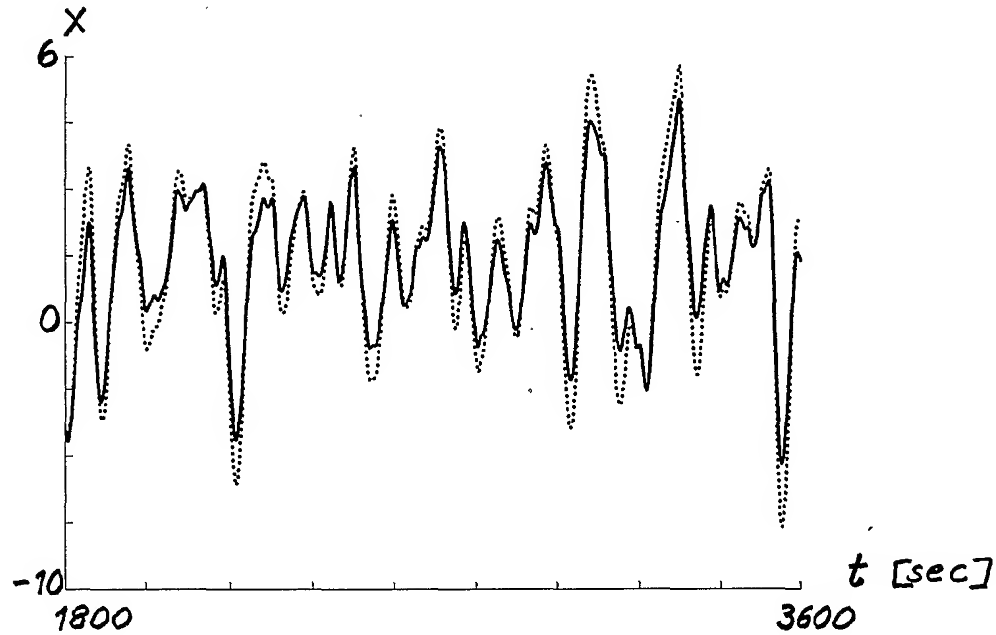

Fig 4

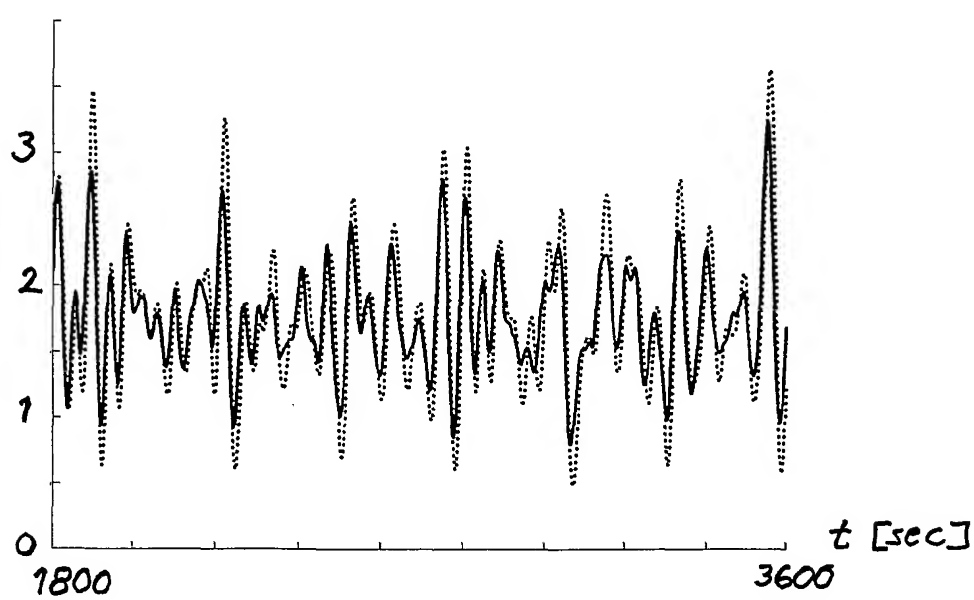

Fig 5

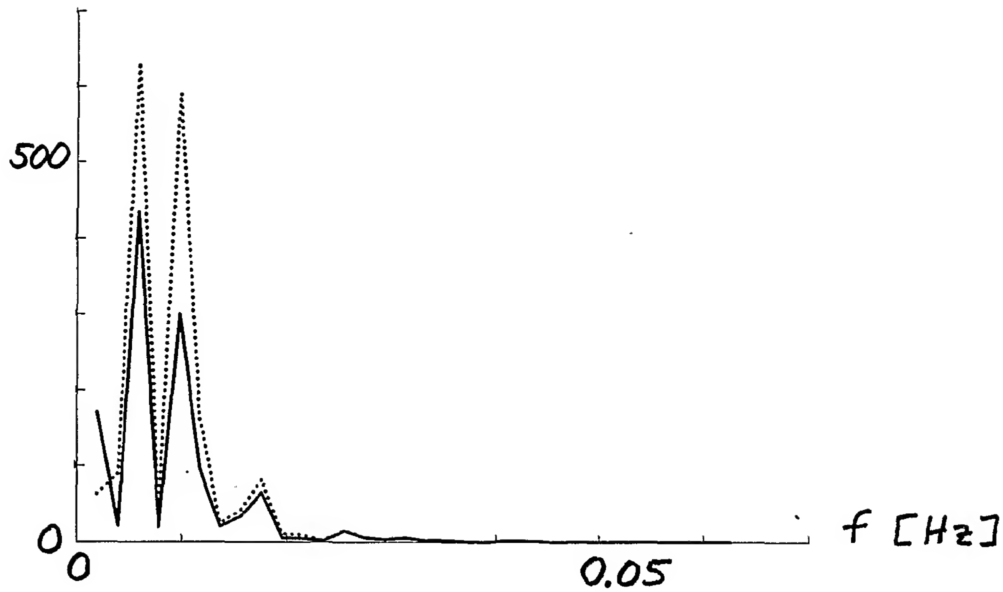

Fig 6

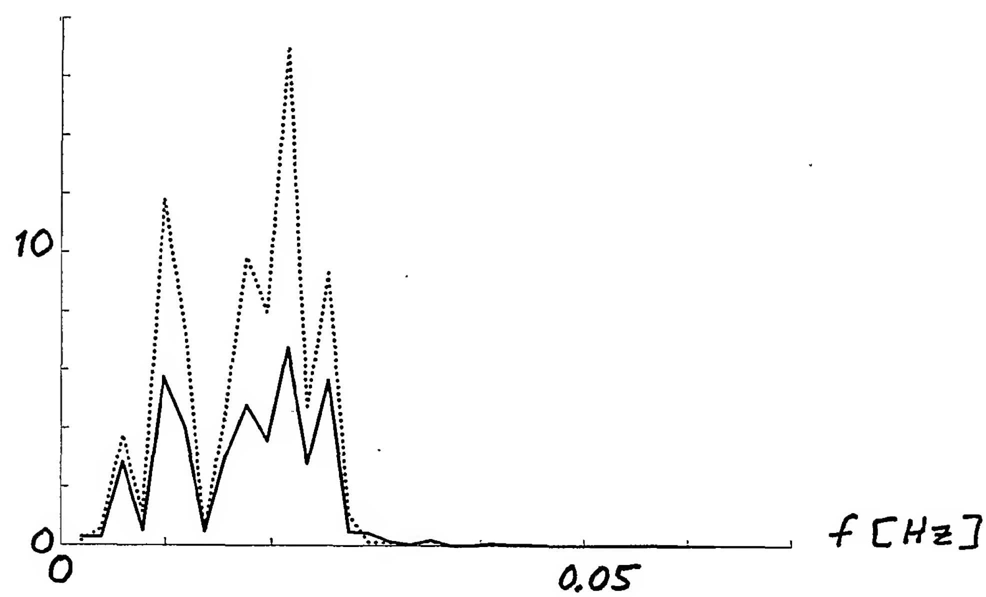

Fig 7

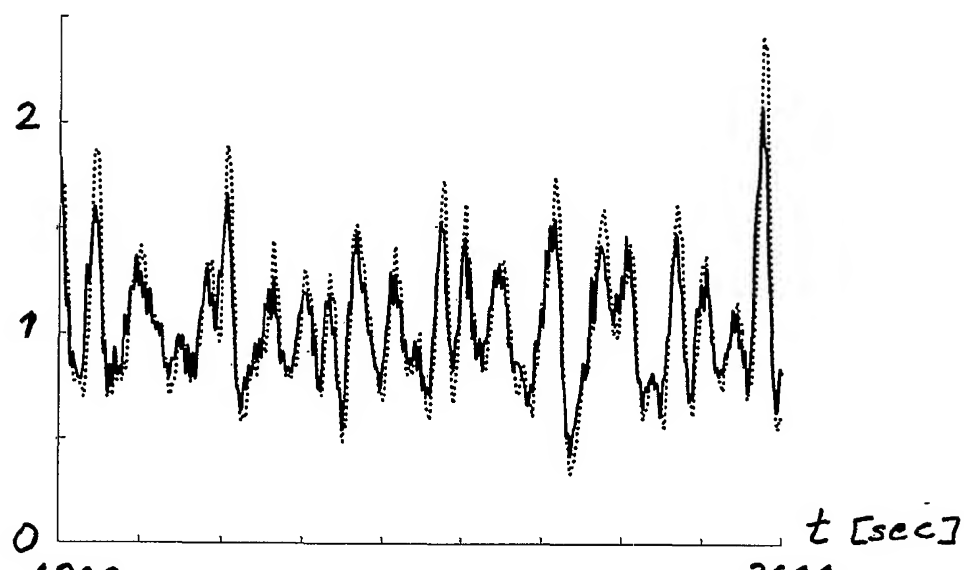

Fig 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB02/00194
PCT/IB 02/00194

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: B63H 25/42, G05D 1/02
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: B63H, G05D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL,WPI.PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3844242 A (F.SERNATINGER ET AL), 29 October 1974 (29.10.74), see the whole document --	1-9,13-22, 24-29,31-36
X	DD 245736 A1 (INGENIEURHOCHSCHULE FüR SEEFAHRT WARNEMüNDE/WUSTROW), 13 May 1987 (13.05.87), claims 1-3, abstract --	1-5,10,11, 13,25-35
A	US 4769773 A (H.L.SHATTO,JR.), 6 Sept 1988 (06.09.88), column 1, line 13 - line 20, abstract --	1-36
A	US 4301760 A (G.CASSONE ET AL), 24 November 1981 (24.11.81), abstract --	1-36

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
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"O" document referring to an oral disclosure, use, exhibition or other means
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 June 2002	11 -06- 2002

Name and mailing address of the ISA/	Authorized officer
Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Göran Magnusson /itw Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/IB 02/00194

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